Computer-Aided Diabetes Education: A Synthesis of Randomized Controlled Trials

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Computer-aided diabetes education is the application of technology to provide information on diabetes self-management as well as test the users' knowledge and provide feedback. The objective of this paper was to evaluate the impact of computer-aided diabetes education in improving health outcomes. We identified reports of randomized controlled trials through systematic electronic database searches. Three eligibility criteria were applied: randomized controlled trial; evaluation of a computerized diabetes education program; and assessment measured on the outcome of patient care. Of 19 eligible trials, 16 trials (84.2%) reported significant positive outcomes. A total of 112 outcomes were identified. Forty-two percent (42.0%) of the outcomes demonstrated significant improvements (47 of 112 outcomes). Considering the importance of patient self-management behaviors in chronic disease management, initial evidence suggests computer-aided diabetes education can play a more significant role in the future.

INTRODUCTION

In the United States, 7% of the population (20.8 million people) has diabetes.[1] Approximately 6.2 million people (30% of 20.8 million) are not aware that they have diabetes.[1] Diabetes is the fifth leading cause of death and accounted for $132 billion in direct and indirect medical expenditures in 2002.[2] Roughly, one third of Americans born in 2000 will develop diabetes in their lifetime.[1] Many people are not aware that they have diabetes until they have developed one of its life-threatening complications.[1]

Quality health care requires effective collaboration between patients and clinicians. Diabetes education is the cornerstone of effective diabetes care.[3] Computerized knowledge management and education can become an important component of quality diabetes care.[4-6] Technology can assist with the provision of tailored and personalized education, feedback, and goal setting, thereby facilitating patient-centered care.

The goals of this study were to identify automated diabetes education interventions that can empower patients in the self-management of diabetes and support diabetes education over a distance. We systematically reviewed randomized controlled trials to evaluate the impact of computer-aided diabetes education on health outcomes. This review was a preliminary step to a larger project.

METHODS

Data Sources

We searched MEDLINE (1966-2006), CINAHL (1982-2006), and the Cochrane Central Register of Controlled Trials (1st Quarter 2006) for relevant studies using combinations of the following search terms: (i) diabetes mellitus (MeSH) or Type 2 diabetes mellitus (MeSH) or Type 1 diabetes mellitus (MeSH); (ii) computer-assisted instruction (MeSH) or computer (truncated textword); and (iii) randomized controlled trial (publication type). We also systematically searched the reference lists of included studies and relevant reviews.

Inclusion and Exclusion Criteria

Our inclusion criteria were any randomized controlled trial evaluating a computerized diabetes self-management education program with assessment measured on the outcome of patient care. We excluded studies that were not randomized, had no control group, were planned studies, or were not in English.

Study Selection and Data Extraction

Two of the investigators independently reviewed the titles and abstracts of the identified citations and applied a screening algorithm based on the inclusion and exclusion criteria described above. The two investigators rated each paper as "potentially relevant" or "potentially not relevant." The investigators collected data from each "potentially relevant" article including educational content topics and outcomes. For each article, the investigators noted the patient sample, intervention, outcome measures, and statistical significance. For the purposes of this study, a trial was successful only if

Table 1. Computer-aided diabetes education trials

Trial, Year	Sample	Control Care	Intervention Care
Bloomfield et al[8] 1990	48 children (type 1)	Routine clinic care (average of 5 visits per year)	Computer-based "diabetic club" educational program, 10 sessions
Brown et al[9] 1997	59 children (type 1)	Entertainment video game	Educational video game "Packy & Marlon," with role playing
Estabrooks et al[10] 2005 *	422 adults (type 2)	Usual care, no goal setting	Computerized touch-screen CD- ROM with goal printout and feedback; counseling session with care manager; telephone follow-up
Gerber et al[11] 2005	244 adults (type 2)	Simple multimedia application with quizzes; no formal instruction	Computerized touch-screen multimedia with formal instruction and testimonials; feedback
Glasgow et al[12-13] 1996, 1997	206 adults (45 type 1) (161 type 2)	Usual care with computerized assessment of dietary management	Touch screen computer- aided assessment with immediate feedback; problem-solving counseling; telephone follow-up
Glasgow et al[14-15] 2004, 2005	886 adults (type 2)	Touch screen computer assessment, printout with general health risks	Touch screen computer assessment and action plan, detailed printout, meeting with care manager
Glasgow et al[16-17] 2000, 2002	320 adults (type 2)	Computerized assessment with goals printout, general pamphlet about low-fat eating	Computerized touch-screen assessment with goals printout, telephone follow-up, community resources
Graue et al[18] 2005	116 children (type 1)	Traditional out-patient consultations (30 min session every 3 months)	Computer-assisted consultations and group visits (3 3-hr sessions every 3 months)
Levetan at al[19] 2002 *	150 adults (type 2)	Usual advice from physician, no additional diabetes education	Computer-generated poster, 10 minutes of telephone follow-up
Lo et al[20] 1996	36 adults (8 type 1) (28 type 2)	Conventional diabetes education program (17 lessons, 4 sessions)	Computer-aided learning (CAL), 16 lessons, 3 to 6 sessions
McKay et al[21] 2001	78 adults (type 2)	Internet information only	On-line tailored "personal coach" to assist in physical activity; personalized feedback
McMahon et al[22] 2005	104 adults (type 2)	Usual care	Web-based care management, messaging system, uploads from monitoring devices
Nebel et al[23] 2004	120 adults (46 type 1) (74 type 2)	Conventional computer-based education program	Adaptive interactive computer-based hypoglycemia education program
Sheldon[24] 1996	13 adults (type 1)	Pencil-paper log, daily food intake and activities, no feedback	Daily food intake and exercise recorded by CADET III with feedback and summary
Smith & Weinert[25] 2000 *	30 adults (type 2)	Printed information and education materials	Computerized education and support using electronic communication technology
Tatti & Lehmann[26] 2003	24 children (type 1)	Conventional lessons with slides and transparencies	Freeware computer program (AIDA downloadable from internet), an interactive educational diabetes simulator
Turnin at al[27] 1992	105 adults (76 type 1) (29 type 2)	Usual care	Computer-assisted diet education through "Diabeto"
Wheeler et al[28-29] 1983, 1985	32 adults (type 2)	1 to 2 nutritional education sessions with dietician	Computer-assisted instruction (CAI) videos, nutritional education, meal planning and dietician support
Wise et al[30] 1986	174 adults (86 type 1) (88 type 2)	Usual care	Interactive computer-based knowledge assessment and instruction

* Intervention care did not lead to any significant outcome benefit ($p<0.05$) when compared with control care.

there was a significant outcome benefit ($p<0.05$) for the intervention (computer-aided) group compared with the control group at follow-up. The investigators analyzed the articles to assess which interventions led to significant or non-significant results. The investigators grouped the outcomes according to the diabetes self-management education core outcome measures continuum: learning, behavior change, clinical improvement, and improved health status.[7]

RESULTS

Comprehensive literature searches identified 87 articles. The titles and abstracts of these articles were read and 31 articles were determined to be relevant. After reading the full articles, eight additional articles were excluded because there was not a computer-aided diabetes education intervention or health outcomes were not measured. Twenty-three articles representing 19 trials met the eligibility criteria (Table 1).[8-30] Three computerized approaches were observed in these trials: computerized touch-screen assessment and instruction,[10-17] computerized assessment with individualized counseling or feedback,[18-25, 27-29] and games or simulation.[8-9, 26]

The total number of patients in the trials was 3167 (2920 adults and 247 children). Adults were subjects in 15 trials and children were subjects in four trials. Five trials focused on insulin dependent diabetes mellitus (IDDM) patients, nine trials focused on non-insulin dependent diabetes mellitus (NIDDM) patients, and five trials involved both IDDM and NIDDM patients. The average trial duration was 7.9 months (range 1 to 24 months).

The evaluated diabetes education content areas included understanding diabetes,[11, 20, 30] self-care & monitoring,[18] prevention & management of complications,[8, 11, 20, 30] emergencies,[23] foot & skin hygiene,[11, 19, 30] oral hygiene,[11] regular eye exam,[11, 19] smoking cessation,[14-15] blood glucose monitoring & recording,[9, 11, 18-20, 22, 26, 30] urine testing,[20, 30] insulin adjustment & administration,[9, 11, 20, 26, 30] medication,[11, 19, 30] diet & nutrition,[8-17, 19-20, 24, 27-30] food purchasing & meal planning,[20, 27-28] exercise & physical activity,[10-11, 14-15, 19-21, 24, 26-27] alcohol,[20] goal setting,[10, 12-19, 21, 28-29] problem solving,[12-13, 21] self-motivation,[21] social support,[18, 25] stress management,[11] social activities,[8] coping,[18] and traveling.[20, 26] There was an average of 4.1 (median of 3) educational content areas per study.

Using the definition for success described in the methods section, significant benefits for the intervention group compared with the control group at follow-up, 16 of 19 trials (84.2%) were successful. Three of the trials were not successful because they failed to show significant beneficial differences between the intervention and control groups on any outcome measure.[10, 19, 25]

One hundred twelve (112) outcomes were measured in the 19 trials. This was an average of 5.9 outcomes per trial. Forty-two percent (42.0%) of the outcomes demonstrated significant improvements (47 of 112 outcomes). Of the types of outcome measures, 10 measured learning (60.0% were significantly improved),[8-9, 11, 20, 23, 28-30] 34 measured behavior change (52.9% were significantly improved),[9-18, 21, 24-25, 27-29] 42 measured clinical improvement (38.1% were significantly improved),[8-20, 22, 24-30] and 23 measured health status (21.7% were significantly improved).[8-9, 11, 14-18, 25] In addition, three measured satisfaction (66.7% were significantly improved).[12-13, 16-17, 21]

Table 2. Significant outcome measures ($p<0.05$)

Learning
diabetes knowledge[8, 23, 30]
dietetic knowledge[27-29]

Behavior Change
fat consumption[12-13, 16-17, 27-29]
calorie consumption[12-13, 27]
carbohydrate consumption[27]
fruit and vegetable consumption[16-17]
general dietary behavior[12-13]
child-parent diabetes communication[9]
computer usage[11, 21]
self-monitoring activities completed[9, 14-15, 24]

Clinical Improvement
weight[28-29]
cholesterol[12-13, 16-17, 22, 24]
hypoglycemic events[8, 26]
blood pressure[22]
hip/waist circumference[24]
physiologic outcomes[12-15]

Health Status
school absences[8]
diabetes intrusiveness[16-17]
diabetes impact[18]
perceived susceptibility to complications[11]
family activities[18]

Satisfaction[12-13, 21]

Thirteen of the trials measured HbA1c.[8-9, 11, 16-20, 22, 24-27, 30] Three of the 13 trials (23.1%) demonstrated a significant improvement in HbA1c levels for the intervention group vs. the control group.[8, 11, 22] Of the remaining trials, five did not demonstrate a

significant difference,[9, 11, 16-18, 24] three provided within group significance but no analysis for between groups,[19, 20, 26] and the significance level was not calculated for two trials.[25, 30] Other significant outcomes measured in the trials of computer-aided diabetes education are presented in Table 2.

DISCUSSION

In this systematic review, we analyzed computer-aided diabetes education interventions measuring health outcomes evaluated in randomized controlled trials. Sixteen of the 19 trials (84.2%) indicated at least one outcome that was significantly better in the intervention group than in the control group.

An underlying principle of patient education is that knowledge is necessary, but not sufficient, to change health behaviors and improve health status. We observed a steady decrease in the percentage of significantly improved outcomes (from 60.0% to 21.7%), as the outcome measures progressed through the continuum from immediate (learning) to long-term (improved health status).

The cited trials studied a wide variety of interventions generalized into three computerized approaches. Many of the trials also featured interventions with telephone follow-up, educational sessions, feedback, and other resources. Certain types of interventions may be successful whereas others are not. When interventions lead to comparable outcomes, the more feasible or less costly intervention should be selected. Unfortunately, none of the trials in this review provided cost information. Further review of the cited literature is proposed to understand which interventions had significant effects on which outcomes.

Our results indicate that the most common education content areas were diet & nutrition (13 trials), exercise & physical activity (nine trials), blood glucose monitoring & recording (eight trials), and goal setting (eight trials). This is not surprising since these areas are the most important ways to control diabetes.[31] Goal setting and feedback are also important patient centered care activities for the long-term management of diabetes.[32-33]

As the prevalence of chronic disease increases and the population of the United States ages, there will be a greater opportunity for computer-aided diabetes education to play a significant role in the future. It is important to know that there have been randomized controlled evaluations that indicate health outcomes improvement.

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